Variability of perfusion dark rim artifacts due to Gibbs ringing

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Background and Aims

Gibbs ringing is a well known source of Dark Rim Artifacts (DRA) in myocardial perfusion imaging [1]. We examine the variability of this artifact. Specifically, we show that Gibbs artifacts are highly dependent on the endocardial border position in relation to the image pixels, i.e. that sub-pixel shifts can dramatically change the appearance.

Methods

Sub-pixel shifts were introduced in 5 *in-vivo* raw-data perfusion studies, where a DRA was visible. The shifts had a step of $1/8^{th}$ of a pixel ranging from 0.125 to 0.875 of the in-plane pixel size. The unprocessed raw-data was phase-shifted using MATLAB before reconstructing it on the scanner using the same image processing as the original data.

The original perfusion studies were done on a 1.5 T scanner (Avanto; Siemens): hybrid-EPI sequence with an EPI factor of 4; TR/TE of 5.1/1.7 ms; base resolution 128 pixels; pixel size 2.8x2.8x8 mm; flip angle 30 °; bandwidth 1860 Hz pixel^{-1}; TI (time of inversion) of 90ms using a non-selective BIR-4 saturation pulse, TSENSE with R=2. Perfusion was imaged during first pass of Gd-DTPA while at stress induced by pharmacologically by adenosine.

The different sub-pixel shifted data was interpolated using two different methods: an image based bicubic interpolation by a factor of 2, and an interpolation pre-FFT by zero filling the raw data also by the same factor. The DRAs shown were carefully selected so as to not coincide with any known real perfusion defect.

Results and Discussion

Figure 1 shows four consecutive frames during the arrival of the CA into the myocardium for a perfusion patient, in the basal slice for two different sub-pixel shifts and also for two different interpolation methods. The original data had two DRAs visible, one located in the inferior segment and another located in the superior segment, as pointed by the white arrows in Figure *a*. On the top left it is shown the shifted data that yielded the most prominent DRAs, with the four frames interpolated in the image space, Figures *a-d*. On the bottom left it is shown the image space based interpolation images for the shift that yielded the least prominent DRAs in the same segments, Figures *e-h*. On the centre, Figures *i-l* show the same data as Figures *a-d*, but pre-FFT zero filled instead. In a similar fashion, Figures *m-p* show the zero-filled images for the same shifted data as Figures *e-h*.

The vertical shifts for the maximum and minimum visibility of the artifacts in this case were 0.125 and 0.625 of a pixel length, in relation to the original data respectively. The numbers shown on the image based interpolation frames are the loss of signal in the DRA region, when compared to the average myocardial signal for both DRAs' segments.

Figures *a-d* shows much more prominent DRAs in both segments than the same corresponding frames in Figures *e-h*. In particular, the DRA in the inferior segment is not visible in Figures *e-h*. In contrast, the artifacts appear consistently without regard to the inplane offsets in the zero-filled data, when comparing Figures *i-l* with Figures *m-p*, with both sets yielding approximately the same signal losses as Figures *a-d*. Similar results were obtained in all 5 patient cases examined.

The same dependency on the sub-pixel position of a sharp edge was confirmed in a Phantom, Figure *q-s*, where it can be seen, in image *q* (uninterpolated), and *r* (image based interpolated) that the near-horizontal edge generates Gibbs artifacts at some locations along the horizontal direction (solid arrows) but not at others (dashed arrows), this effect is not visible in the zero filled image *s*. Numerical simulations also confirmed the findings (results not shown).

This dependency in the image based interpolated images can be explained by the averaging of the Gibbs ringing signal oscillations inside each pixel, while zero-filled interpolation upsamples the same oscillations before FFT, reducing its dependency on the edge position relative to pixel locations [2].
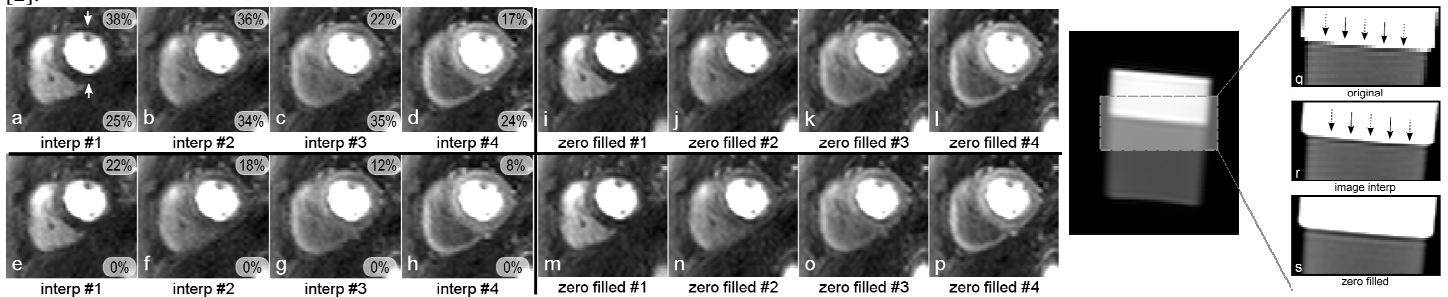

Figure 1: Figures *a-p* show 4 consecutive perfusion frames compared for two different interpolation methods, and also for two different vertical sub-pixel shifts of the original data. Figures *q-s* show a phantom with a sharp nearly horizontal edge.

Conclusion

The visibility of Gibbs DRAs in perfusion studies is very dependent on the position of the subendocardial wall inside the pixel in the absence of zero-filled pre-FFT interpolation. Position variations from frame to frame in a typical gated perfusion study can explain some of the variability often seen in DRAs. Interpolation by zero-filling prior to enlarged FFT regularizes the DRA appearance.

References: [1] E Di Bella, et al., MRM, 54(5):1295, 2005. [2] Y Du, et al., JMRI, 4(5):733, 1994.